Design and Implementation of a Motion Control Program to Assess the Consistency of the Flying Wire's Feedthrough and Coupling

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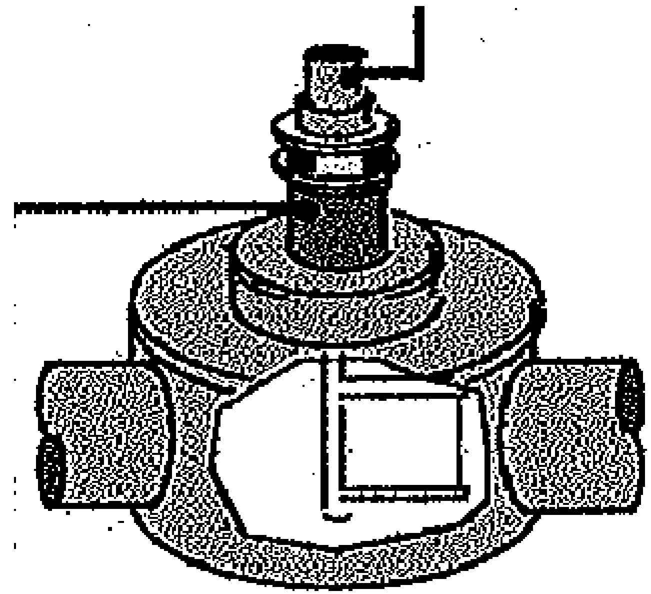
Overview

- Introduction
  - What is the "Flying Wire"?
  - Why are we studying it?
- Tools and Methods
  - Designing circuits
  - Programming the Elmo Solo Whistle
  - Assembling the test setup
- Results
- Conclusion

What is the Flying Wire?

- The Flying Wire is utilized to detect and measure the size of the beam in the accelerator.
- The profile of the beam can be determined by passing a wire through it.
- Contains a carbon fiber filament, which has a diameter of 7 micron.
- The position of the wire is determined through a resolver.



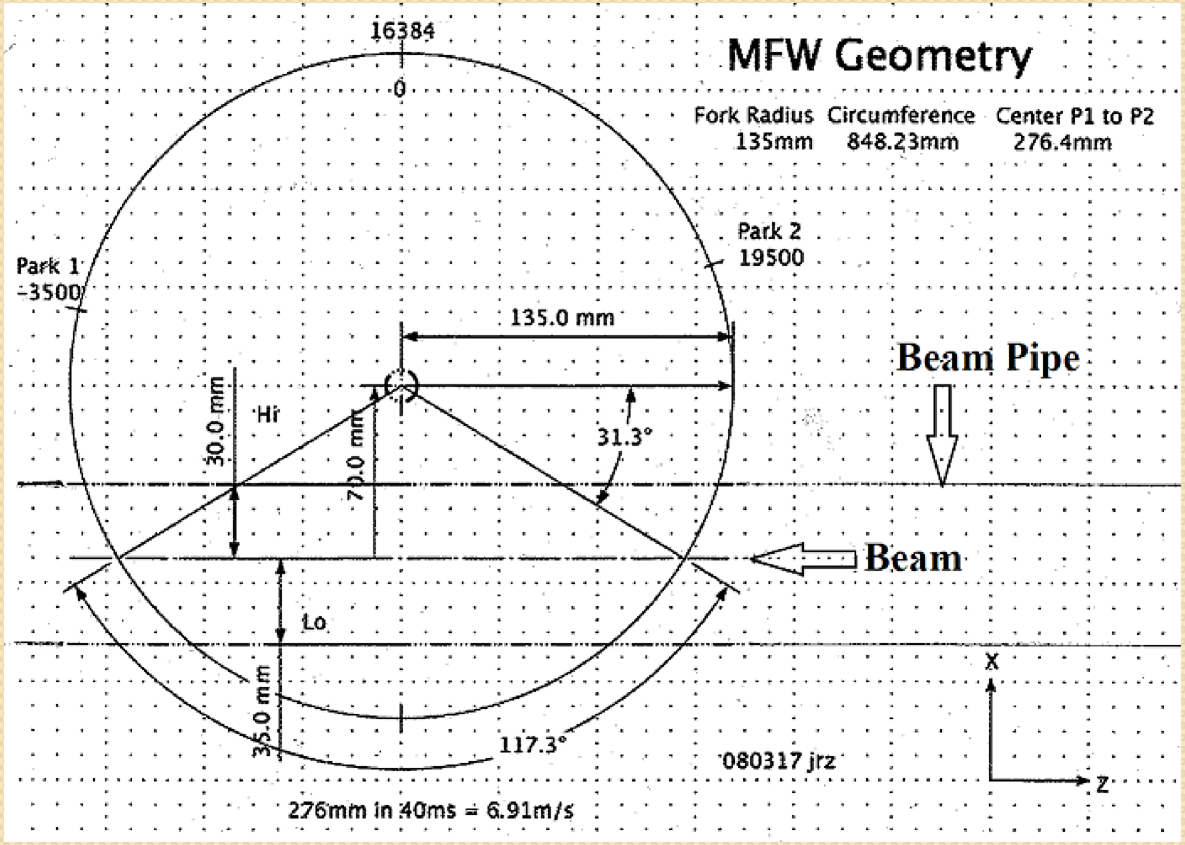
Wire Assembly

More About the Flying Wire

- Secondary particles are produced when the wire collides with the beam.
- The secondary particles are detected by an adjacent scintillator paddle that will produce light.
- A photomultiplier tube transforms the light into an electrical signal, which is charted to provide a profile of the beam.

FLYING WIRE PATH

The Flying Wire has to complete a path that totals 540 degrees. During the fly, the wire accelerates fast in order to pass through the beam twice and then decelerates.



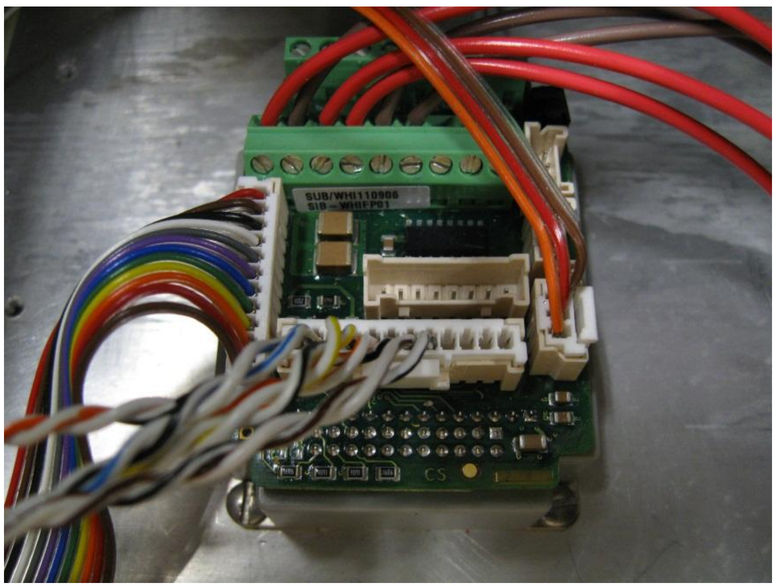
Current Flying Wire System

- Current system uses a resolver, which is immune to radiation damage.
- The current system works, but has experienced premature bearing in the feedthrough and coupling failure.

Why am I doing this research?

- The purpose of this project is to see if the coupling and feedthrough of the Flying Wire test setup can withstand a year's equivalent of rotations.
- A year's equivalent is about 36,500 rotations, which is around 100 flies a day.
- The time calculated to complete this test is around 1.6 days.

Elmo Solo Whistle Servo Drive



- It is a motion control drive that contains a high level programming environment.
- A DC power source is used to operate the in current, velocity, and position modes.

Optical Incremental Encoder

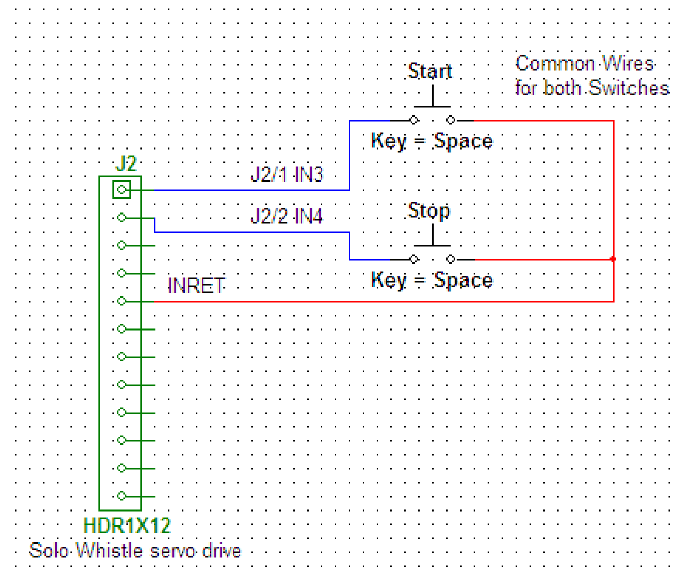
- Contains ABEC class 7 bearings and a chrome-on-glass disc.
- Disc contains 3 different pathways: A, B, and Z.
- A and B paths have 4,096 markings.
- Z path contains the index, which is a single marking.

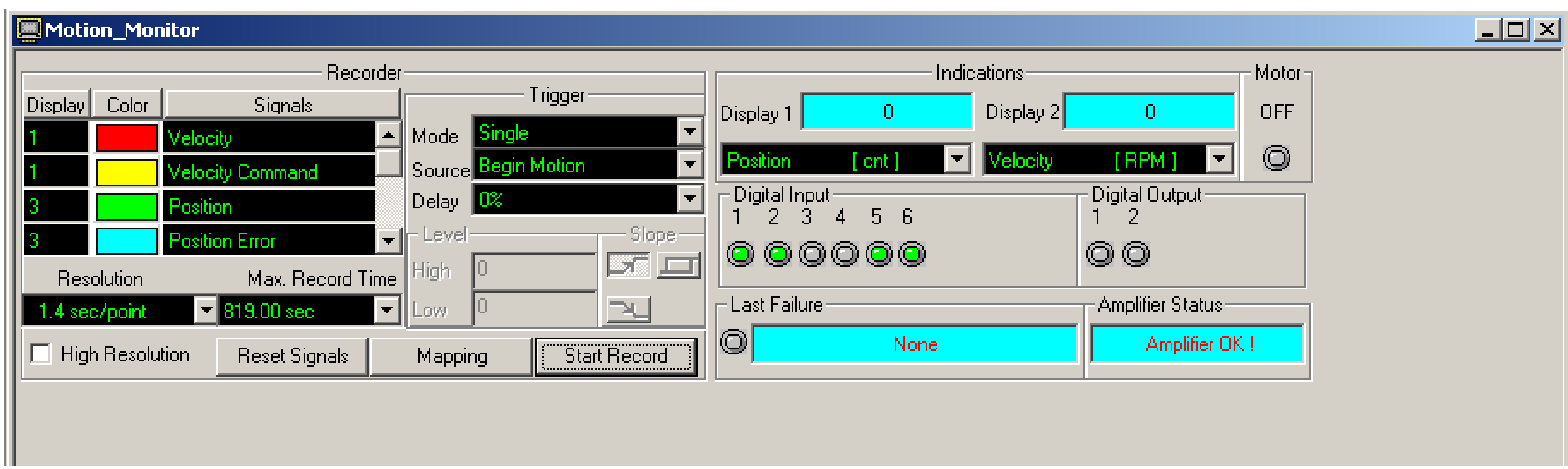
Requirements of the Motion Controller

- Begin/Stop the motion
  - Start and Stop buttons
- Count the number of rotations
  - Counter
- Indicate the status of the program
  - LED

Designing the Start/Stop Circuit

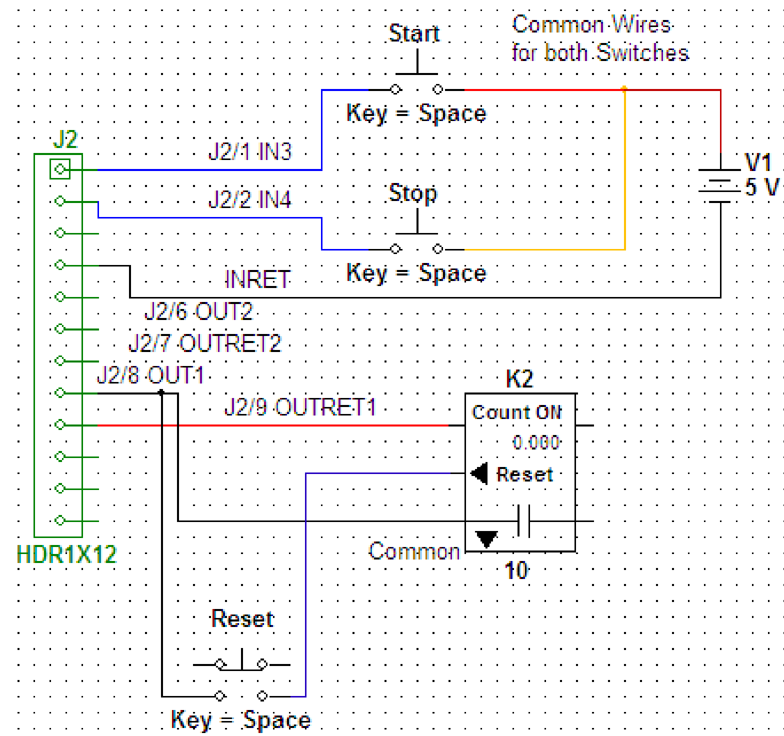
- First attempt of designing the Start/Stop buttons
- Did not work when tested





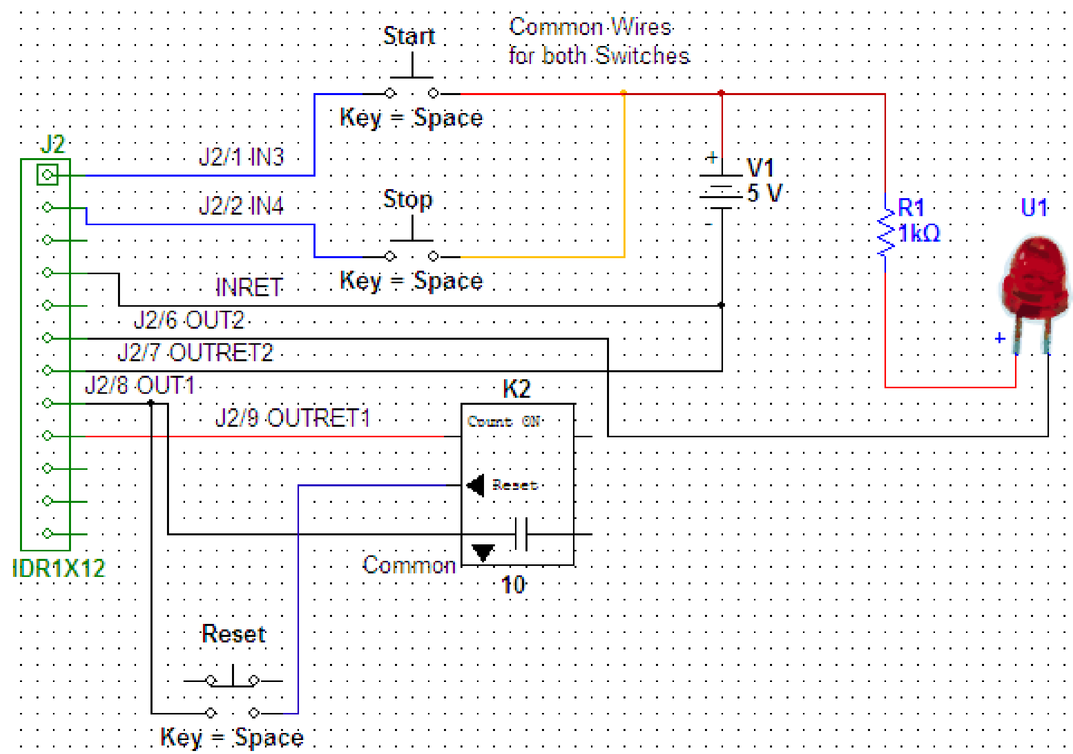
Second Attempt: Start/Stop Buttons and Counter Circuit

- Start/Stop buttons needed 5 V power supply.
- Counter was added to the circuit output.
  - It didn't require a power supply.
- Reset button on counter was disabled.

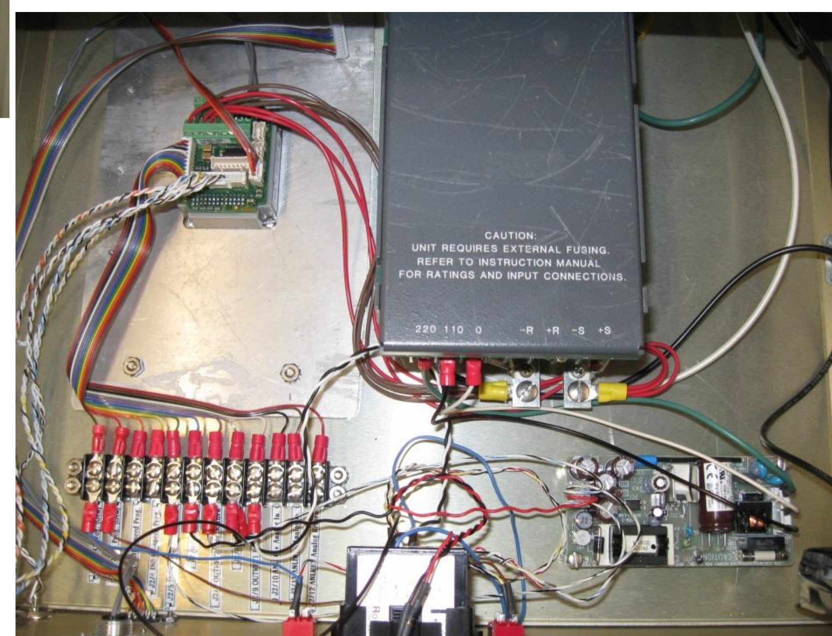


Adding the LED

- The LED required a 1kΩ resistor because the 5 V power supply that would be utilized.

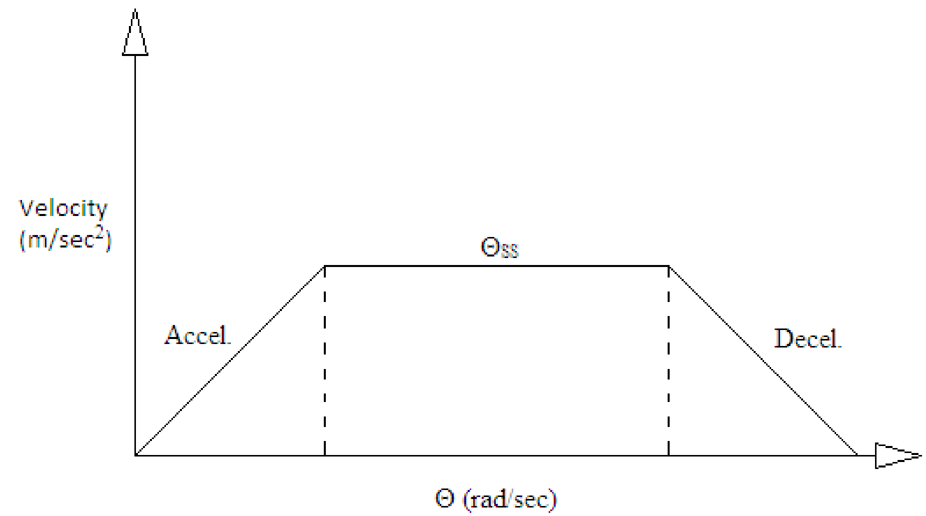


Completed Circuit Design



Ideal Velocity Profile

- Motor control systems basically have a velocity profile similar to the Flying Wire's velocity profile.
- All of this motion has to occur within a window.
- In order to achieve the profile shown, the Flying Wire system has to be tuned.



First Flying Wire Setup

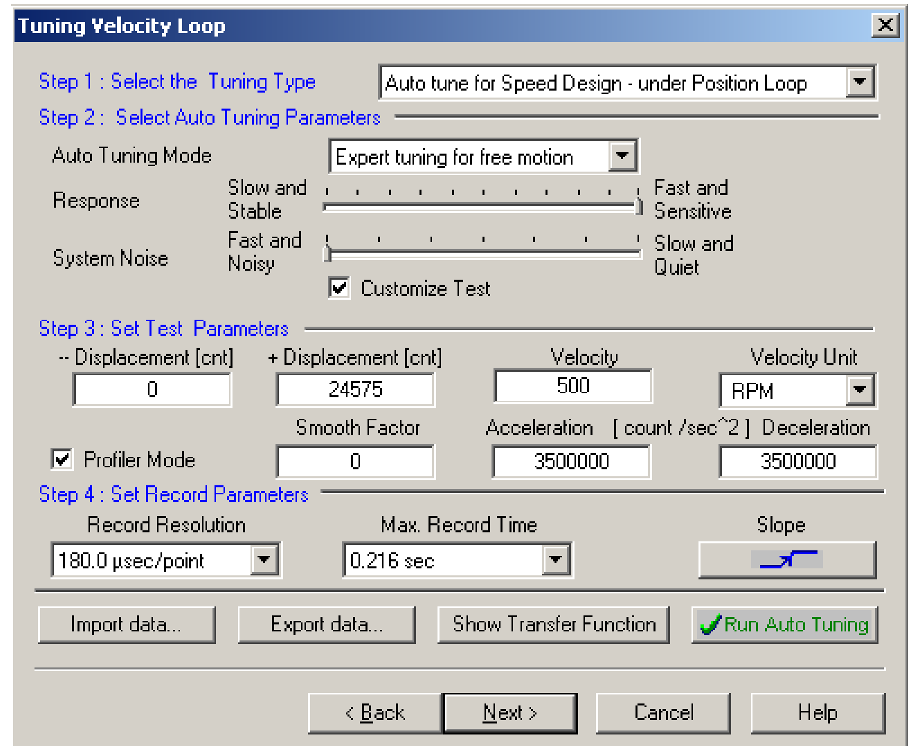
- First Flying Wire setup used to set the parameters for the second setup.
- This setup was already assembled.

Current Loop

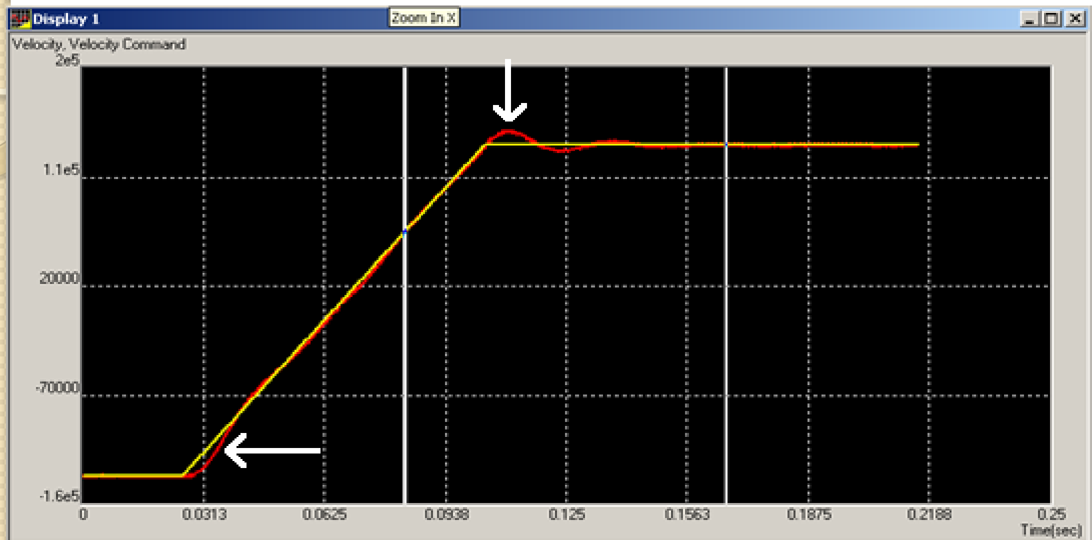
- The first process to tune because it is the most basic control loop.
- This step energizes the motor winding with a high-frequency current, in order to identify the dynamic response for resistance and inductance.
- When this test is complete, an array of auto-tuned current controller factors is created

Velocity Loop

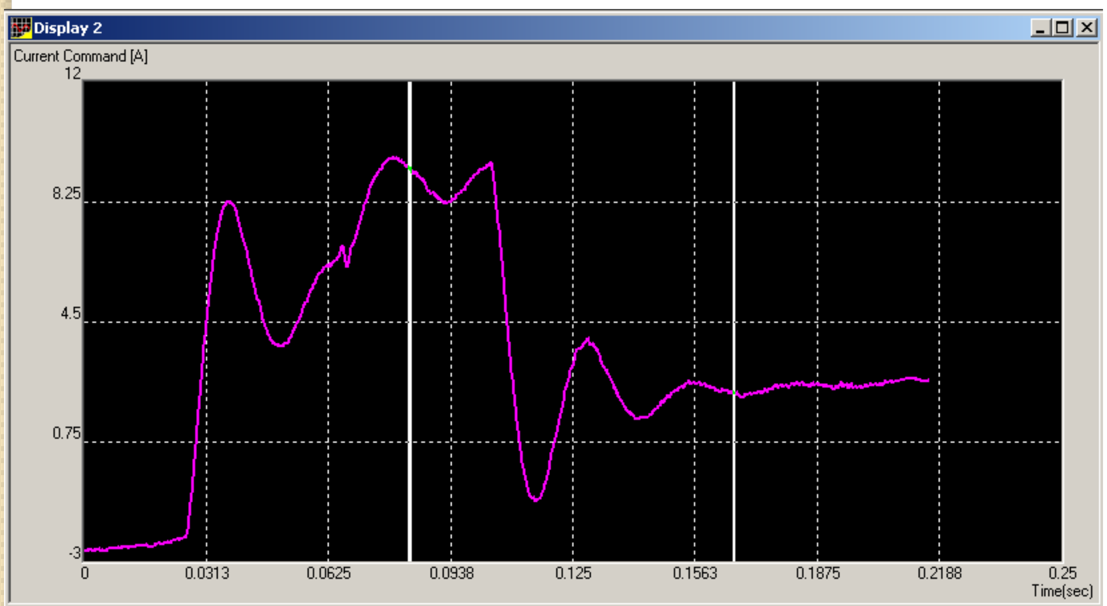
- This step adjusts the velocity loop and sets an optimal balance between control gains and precise motion on the one hand; and higher stress, measurement and quantization noise on the other.



Velocity Loop Test Results



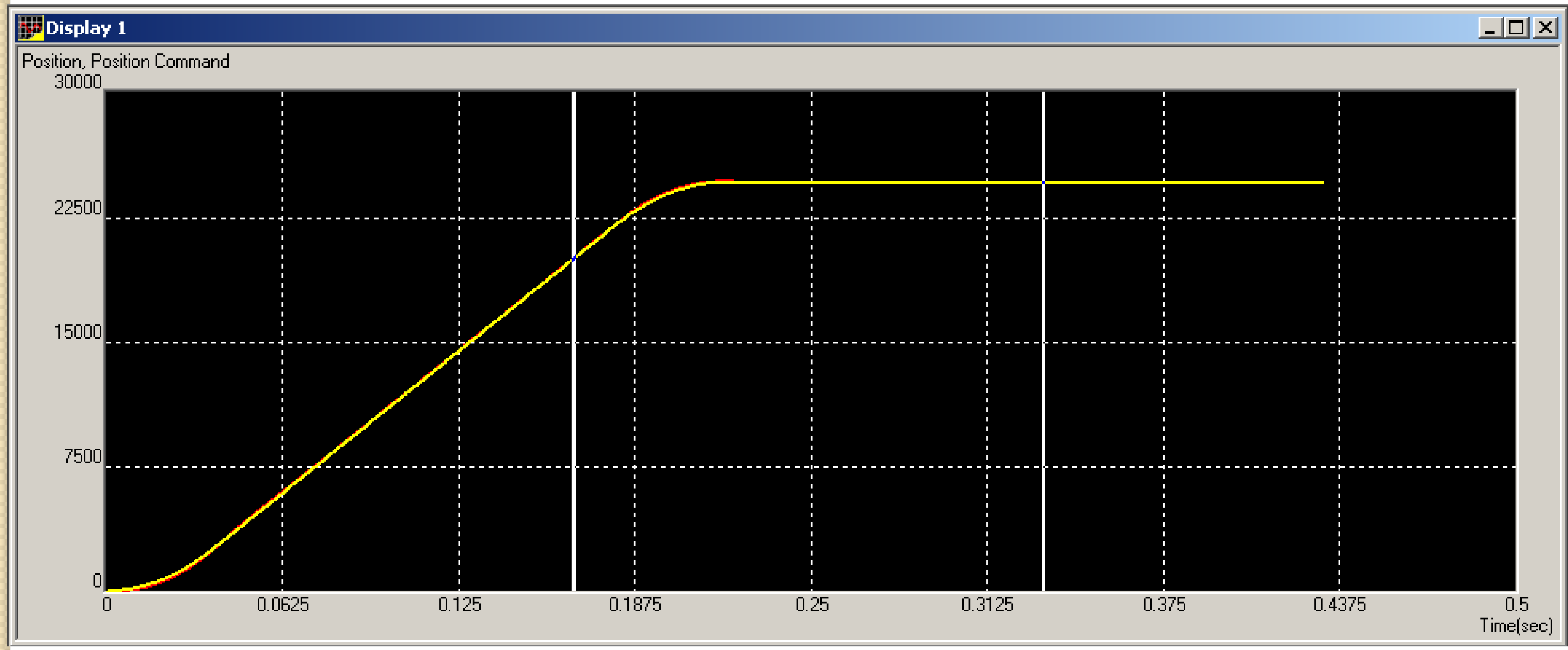
Velocity/Velocity Command Graph



Current Command Graph

Position Loop

- This process tunes the motor to make sure it starts and stops in the correct position with minimal error.

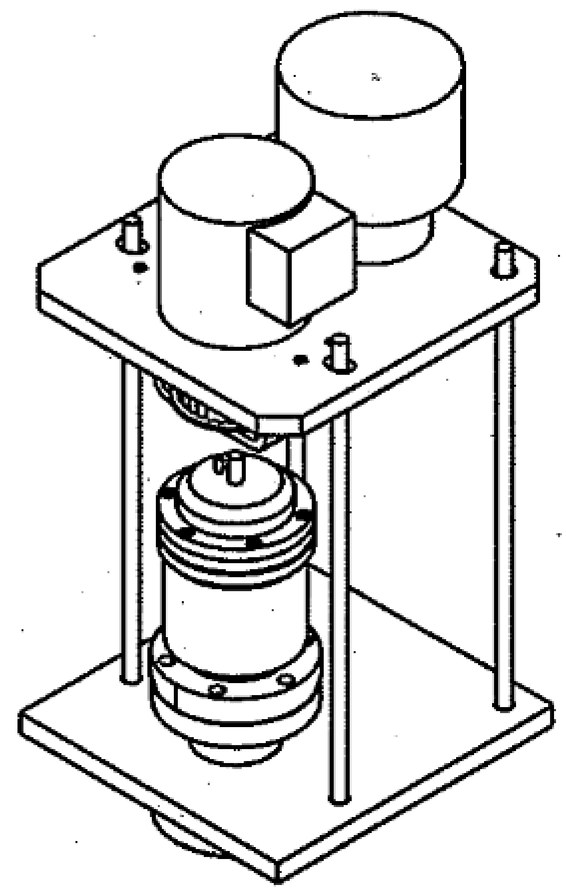


Program Capabilities

- Begin movement once the Start button has been pressed.
- Stop movement once the Stop button has been held for about 2 seconds.
- Increment the value on the counter.
- LED indicate program status:
  - Blinking slowly– program is working
  - Blinking fast – program cycles are complete
  - LED on – stop button has been pressed

Assembling the Second Setup

- Designed by a mechanical engineering co-op student.
- Assisted in building the second setup



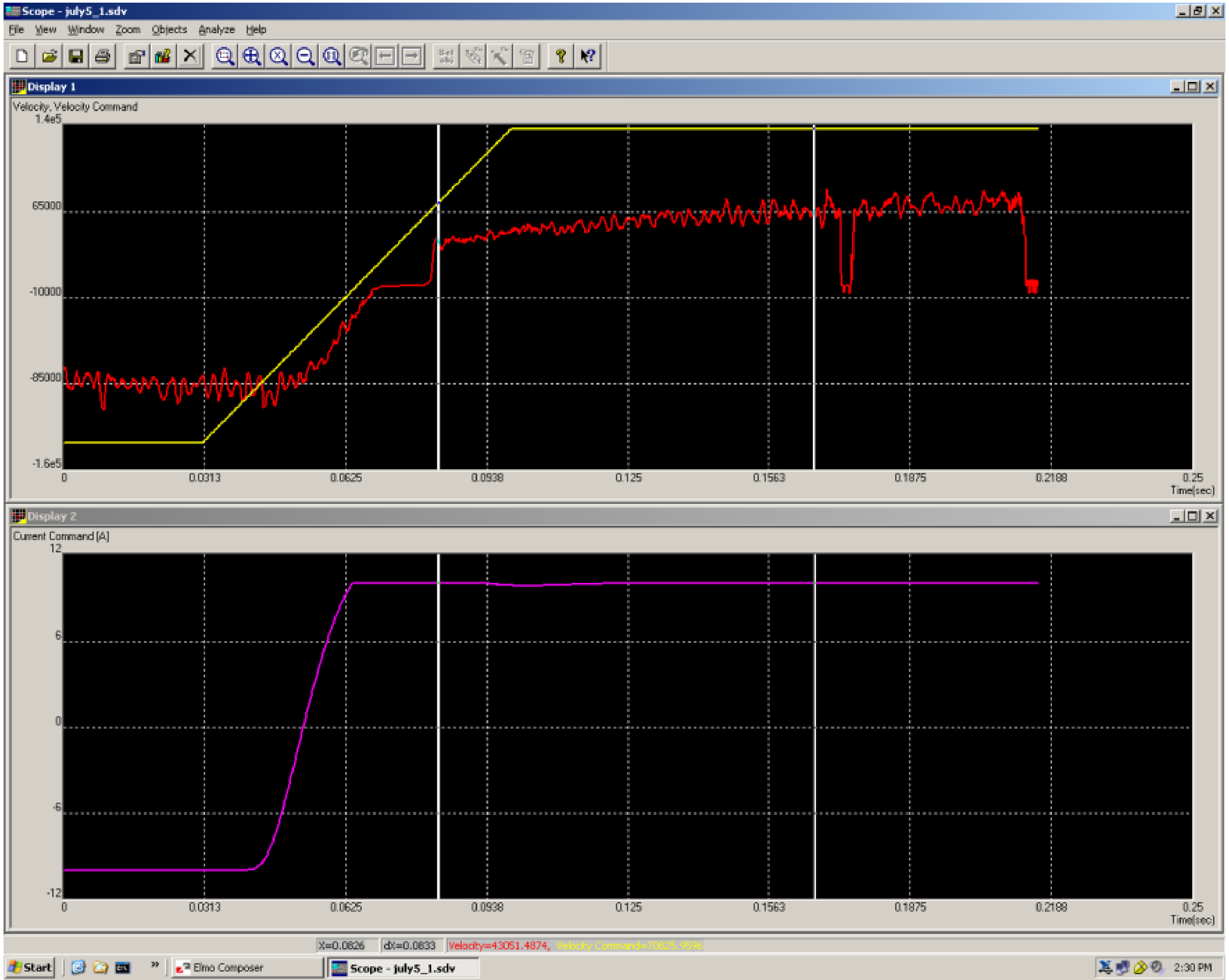
Troubleshooting in Second Setup

- While finishing the construction, it was found out that the diameter of the inertial slug for the feedthrough was the exact diameter of the slot it was supposed to be in.
- While waiting for the new inertial slug, the second test setup was auto tuned to provide the best results with minimum error.

Tuning the Second Setup

- Failed while in the current loop due to:
  - The size of the load (feedthrough)
  - Friction in the system
- Due to this failure, the system had to be manually tuned.
- With friction, the motor required more torque and more current to rotate the feedthrough faster.
- Motor could not be provide the required amperage because of Elmo drive limitations.

Results of Velocity Loop Test



Results of 1 Year's Equivalent of Rotations

- The test system was found off the next day after leaving it overnight.
- It powered off internally once the separation occurred.
- The coupling broke after 7,706 rotations, which is around 8.13 hours.

Why Did the Coupling Break?

- Flying Wire setup had a misalignment of about 3 to 4 millimeters.
- The coupling was supposed to axially aligned between the motor and the feedthrough.
- The coupling provides the flexibility necessary; however, the offset was too great since it can be visually seen.

Conclusion

- The coupling did not survive to the end of the analysis.
- Due to misalignment of the test system, it was not able to complete the allotted number of cycles; therefore, the test system did not operate a year's equivalent.
- The test system operated for an equivalent of about 2.5 months.

Future Work

- The components of the system will be analyzed to establish that they are correctly measured to the mechanical schematic to prevent misalignment.
- Test setup with inertial slug in vacuum needs to be tested.
- More trials would have to completed to establish how long the coupling and feedthrough can last.

Acknowledgements

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References

- Blokland, W. . *A New Flying Wire System for the Tevatron*. Batavia.
- *Elmo* Motion Control. (2010). *SimpleIQ Software Manual*.
- *Elmo* Motion Control. (2010). *Solo Whistle Digital Servo Drive Installation Guide*.
- Fermilab. (2002, July 2). *Inquiring Minds*. Retrieved July 2011, from Fermilab: http://www.fnal.gov/pub/inquiring/physics/index.html

Questions?